The Intersection of Robust Intelligence and Trust: Hybrid Teams, Firms, and Systems

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Abstract

We are developing the physics of interdependent uncertainty relations to efficiently and effectively control interdependence in autonomous hybrid teams (i.e., arbitrary combinations of humans, robots and machines), which cannot be done presently. Uncertainty is created in states of interdependence between social objects: at one extreme, interdependence reduces to independent agents and certainty but with asocial, low-power solutions generating little meaning or understanding in social contexts; oppositely, the length of interdependence increases across a group, deindividuating its members until individual identity dissolves (e.g., cults, gangs, well-run teams), increasing power, efficiency and meaning, but also the chances of maladaptation (e.g., tragic mistakes). We focus on how interdependence increases the robust intelligence of a group by increasing its autonomy while decreasing its entropy, but requiring external control to be indirect. For humans, teamwork is an unsolved theoretical problem; solving it should generalize to the effective computational control of hybrid teams, a path forward for the users of a team to trust it to operate safely in hostile environments. Present theories of interdependence, like game theory or social science, are inadequate to formulate strategies to control teams; alternative theories like machine learning can control swarms with pattern formations, but not interdependence, such as multi-tasking operations. While alternative theories cannot be used to model teams, decision-making and social conflict (hostile mergers; checks & balances) at the same time, ours can.

Introduction

Our goal with autonomy is to control hybrid teams (arbitrary combinations of humans, machines and robots). Traditional approaches to social models treat interdependence as a problem to be removed to improve experimental replicability (Kenny et al., 1998), or one to be resolved before teams can be controlled (e.g., Jamshidi, 2009). In contrast, Lawless considers interdependence as a resource that *solves* ill-defined problems (IDP). But, as costs, predictability and replicability are lost. Unlike swarms, machine learning and game theory approaches to interdependence, we conclude that hybrid teams, like human teams, cannot be controlled directly to solve IDPs; instead, they can be indirectly controlled with self-governance (Lawless et al., 2013).

The difference in approaches is foundational. Traditional approaches assume a complete, "God's-eye view" of reality, implying that whatever information can be sensed can be collected to model social reality (Rand & Nowak, 2013, p. 415). In contrast, the physics of interdependence (Signal Detection Theory) precludes completeness, limiting the information that can be sensed or collected by machines or humans, physically constraining meaning and situational awareness. The approach suggested by Lawless generates better models of social reality with concrete conclusions; e.g., incomplete social information causes uncertainty; social autonomy cannot occur without social interactions; and autonomy is a resource when benefits exceed interaction costs (Coase, 1960).

In addition, we plan to continue to perform research on the autonomy of hybrid teams. Our research is centered around signal detection theory (SDT); social interdependence or bistability (i.e., multiple states); multitasking; and Nash equilibria. Individuals multitask poorly (Wickens, 1992); teams and firms exist to multitask (Ambrose, 2001; e.g., a baseball team multitasks when its members play different positions). Unlike traditional game-theoretic models which promote cooperation but not governance (e.g., Rand & Nowak, 2013), Nash equilibria are one of the primary tools of social self-governance where a society multitasks by exploiting the competition naturally existing between the orthogonal (bistable) beliefs of groups in processing the signals or information they emit to solve the IDPs that improve its social welfare (Lawless et al., 2013).

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Game theory models of social reality do not attempt to be "a good representation of that world." (Rand & Nowak, 2013, p. 416). They assume that only one view of reality is possible. In contrast, bistability assumes that two orthogonal interpretations spontaneously arise in every social situation (e.g., Republicans and Democrats come to differing or orthogonal interpretations of reality). Thus, our bistable models better capture existing social reality (e.g., Lawless et al., 2013). This result has important implications, as when attempting to reduce tragic decisions; e.g., during the time that DOE contaminated the environment with widespread radioactive wastes, now costing up to $200 billion to remediate, DOE was self-regulated (Lawless et al., 2008), whereas today, its decisions are competitively challenged by numerous State and Federal agencies and the public, yet the quality of its decisions has improved dramatically (Lawless et al., 2013).

Background

Biologists approach studies of nesting agents with open minds about a nest's welfare, an approach made difficult in the study of human teams, groups and systems by the cognitive biases that have impeded the development of a new mathematics of interdependence to replace game theory (e.g., Barabási, 2009).[1] Interdependence theory is needed for the efficient and effective control of autonomous hybrid teams (Lawless et al., 2013), an arbitrary combination of humans, machines and robots, in preparation for a rapidly approaching future with computational teams.[2] But since the introduction of interdependence into game theory almost 70 years ago, it has floundered (Schweitzer et al., 2009) likely because its assumptions have never been validated; e.g., cooperation is valued over competition;[3] interdependence is treated as a static or repeated static phenomenon (e.g., like the movies); and, more relevant, with its folk theorem, the choices made by a team are determined by a simple sum of the individual choices of its members.

These biases extend to the social science of teams, where interdependence is a nuisance to be removed for valid experiments (e.g., Kenny et al., 1998). The study of interdependence is encumbered further by the cost in collecting an increasingly large number of teams as team size increases in order to reach statistical significance. To reduce costs, most studies of teams focus on small three-member groups, usually concluding that cooperation among members produces superior results compared to competition (Bell et al., 2012); while we agree, groups with three to six members are hampered in generating competition (Kerr & MacCoun, 1985), a problem not only for say juries weighing alternative decisions, but also for the theory of groups. In field studies, for example, Hackman (2011) concluded that conflict (competition) in teams made them more creative; supporting Hackman, in our study of citizen groups advising the Department of Energy (DOE) on the cleanup of its wide-spread radionuclide contamination across its complex, we found that observing conflict is sufficiently entertaining to hold an audience's attention as a group generates the information needed to decide on a course of action, that competition among viewpoints produced more concrete recommendations that advanced DOE's cleanup compared to consensus decisions (Lawless et al., 2008); and in the lab, that the larger the group size, the more conflict and interdependence it generates, along with better decisions (Lawless, 2014).

In sum, the poor state of team theory impedes generalizations from teams to higher orders of organization; compared to systems that enforce cooperation, competitive checks and balances significantly improve social well-being; and a new method must be found to replace the costs of running experiments with larger group sizes, which raises questions about the applicability of laboratory experiments to real problems (Kerr & MacCoun, 1985). Also, when the institutions (cooperative social structures) that allow the existence of competition to improve social well-being themselves arbitrarily change the interpretations of their own rules, transactional uncertainty increases.[4]

Theory

Interdependence is the effect of a group on the individual, ranging from a minimum for independence (e.g., individuation into individuals), to a maximum with the disappearance of the individual into a group (e.g., deindividuation into a mob or swarm). Interdependence causes teams to form into organizations (independent person A does x; person A sells item x to anyone, say independent person B who does y; person B sells combined xy item to anyone, say independent person C who does z; etc.; these actors are performing independent tasks until two or more independent actors become dependent on each

[1] Helbing (2013): "… we need to 'think out of the box' and require a paradigm shift towards a new economic thinking characterized by a systemic, interaction-oriented perspective inspired by knowledge about complex, ecological, and social systems."

[2] New York Times, Keller, B., Op-Ed (2013, 3/16) "Smart Drones".

[3] But cooperation between two competitors, like Apple and Google, is known as collusion; in Lawless et al., 2011.

[4] For example, compare the Wall Street Journal (2013, 10/11), "Opinion: Looting JP Morgan", with New York Times (2013, 9/30), "Despite its cries of unfair treatment, JP Morgan is no victim".

other, forming multi-tasking communication channels between a team's members with the flow of information, objects and material; they can form an organization when the money -- energy -- generated is greater than their losses--entropy; in Coase, 1937); but interdependence causes uncertainty (on the assembly line, normally person A is paid to do *x* and person B is paid to expect *x* to combine it with *y*, a team becomes trusted; but when person A does something unexpected, person B is left confused about what to do, illustrating interdependence and uncertainty). Measurements of uncertainty cause incompleteness; e.g., religion, politics or sororities all require specific actions and beliefs for membership--to get to the upper echelon of a group requires that an agent master its rituals and beliefs, implying that for trust to increase among fellow members, the leader must become a "true" believer; but when the agent fully adopts these beliefs, an incomplete view of reality is formed; i.e., it becomes less able to predict its competitor's actions reducing trust in the competitor.[5] Subsequently meeting counterparts in opposing groups illuminates incompleteness (political party A meets opposing political party B for a discussion which highlights their mutual uncertainty;[6] or computer firm member A of Apple disagrees with a colleague at Apple;[7] or a member A of computer firm Apple meets member B of computer firm Google, causing disagreement;[8] etc.).

The result of conflict is information (from information theory; Conant, 1976); with mutually acceptable structures, illustrating socially appropriate cooperation among competing groups, information can be converted into actions that improve social welfare (increasing free energy), characterized as knowledge (generating low entropy). Consequently, we assert that an institutionalized conflict center, which we call a Nash equilibrium (NE), is a social asset that helps those societies evolve that can manage an NE, compared to those that cannot or would not.[9] We also assert that knowledge for social transactions cannot be otherwise generated (from Coase, 1960).

Outline of the mathematics

*Field Model***.** Putting uncertainty aside until later, the effects of a community matrix *A* can be measured in the field. Assume that competition for resources occurs within and between groups; that, unlike the inability of individuals to multitask (Wickens, 1992), multitasking is the purpose of a group (Ambrose, 2001). The optimal group multitasks seamlessly, generating a baseline entropy for stable organizations that we initially, but incorrectly, set to zero, noting that, similarly, stable knowledge implies zero entropy (Conant, 1976). We justify this assumption at this time by observing that, compared to functional groups, an individual is less able to survive. That is, a collective of individuals is in a higher state of average uncertainty or agitation than the same individuals independently performing the identical actions but as part of a group using coordination to multitask.

Competition between groups increases cooperation within groups (Bowles, 2012). Given *A* as an operator that serves as a community matrix of, for example, possible cooperators working together to multi-task by a tribe's ingroup, or competitors in an outgroup, let a_{ij} represent the effects of *agent-i* on *agent-j*, the opposite for a_{ji} (May, 1973; for ingroup-outgroup effects, see Tajfel, 1970; for tribal effects, see Chagnon, 1988). The strength of cooperation to multi-task can be measured by the state of interdependence in community matrix *A*, where interdependence is the effect that a group has on the choices and behaviors of its members; we designate interdependence as ρ:

$$\rho = (MS_{G/T} - MS_{S/G/T})/(MS_{G/T} + (n-1)MS_{S/G/T}), \quad (1)$$

[5] As happens during a hostile merger; e.g., Wall Street Journal (2010, 1/12), "Kraft, Cadbury close to $19 Billion Deal", wsj.com.

[6] ""But then I get a call from (former US Treasury Secretary) Timothy Geithner," says Schäuble, "and he says, 'You do know that we wouldn't have made the decision to allow Lehman Brothers to go bankrupt if we had been asked 24 hours later, don't you?'" Schäuble shrugs his shoulders and falls silent. He cradles his head in his hands and narrows his eyes, using body language to ask: Well, what do you do in that situation? What's the right thing to do? What isn't? What's going to blow up in your face tomorrow?" From Spiegel Online International (2013, 9/26), "Architect of Austerity: Schäuble's Search for a Way Forward", http://www.spiegel.de/international/germany/how-german-finance-minister-schaeuble-navigates-the-euro-crisis-a-924526 html

[7]"... The pressure to meet Jobs's deadlines was so intense that normal discussions quickly devolved into shouting matches. Exhausted engineers quit their jobs — then came back to work a few days later once they had slept a little. Forstall's chief of staff, Kim Vorrath, once slammed her office door so hard it got stuck and locked her in, and co-workers took more than an hour to get her out. "We were all standing there watching it," Grignon says. "Part of it was funny. But it was also one of those moments where you step back and realize how [expletive] it all is."" New York Times Magazine (2013, 10/4), "And Then Steve Said, 'Let There Be an iPhone'"

[8] AppleInsider (2013, 10/4), "Data bites dogma: Apple's iOS ate up Android, Blackberry U.S. market share losses this summer"; http://appleinsider.com/articles/13/10/05/data-bites-dogma-apples-ios-ate-up-android-blackberry-us-market-share-losses-this-summer

[9] Compare night satellite photos of the USA with Cuba; or South Korea with North Korea; or Germany with Russia; from Lawless, 2013.

$MS_{G/T}$ is the sum of the mean squares from the group on a measurement of an arbitrary factor, *T*, such as a culture, an issue or a problem that is a group's focus as it assigns roles that produce multitasking $MS_{S/G/T}$ is the aggregated contribution from the individuals on a measurement of factor *T*; and *n* represents the number of members in a group being measured (from Kenny et al., 1998, p. 235). At its extremes, ρ ranges from -1 as multitasking goes to zero when the group is replaced by a collection of independent individuals; or ρ can range to +1 as multitasking replaces the individual with slavish subservience to a group's efforts, like groupthink or authoritarianism.

With equation (1), we build *A* and convert it into an orthogonal matrix. Let *A* be a symmetric matrix with potential eigenvalues $\lambda_1, \ldots \lambda_n$. If *Q* is an orthogonal matrix with real values, and if $Q^{-1} = Q^t$ (i.e., if the inverse of *Q* equals its transpose), then the row vectors (or column vectors) are orthogonal, and Q^tAQ diagonalizes symmetric matrix *A* into its eigenvalues.

Let *A* be an operator on a social object, ψ, within its internal zone of influence; ψ could be an agent or a team, etc.; and let ψ be a column vector that represents the state of the social object as operator *A* transforms state vector ψ into a matrix. When ψ is represented on two sides of an equation as

$$A\,|\,\psi> = x\,|\,\psi> \qquad (2)$$

then *x* is a scalar that is the eigenvalue, λ, or characteristic of *A*, and ψ becomes an eigenvector or eigenfunction. The usual way to solve for the eigenvalue, λ, is with an iterative process: $A\psi - \lambda I\psi = (A - \lambda I)\psi = 0$, where *I* is the identity matrix (i.e., $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$).

The outer product of two state vectors is an operator; and the outer product of two eigenvectors is a special operator or projector, *P*, that projects an unknown state vector, ψ, into an eigenfunction and eigenvalue. Eigenfunctions form a basis that is orthonormal; i.e., given eigenfunctions ψ and ϕ and $<\psi\,|\,\phi>$ as the inner product of the two eigenfunctions, then $<\psi\,|\,\phi> = \psi_1\phi_1 + \psi_2\phi_2 + \ldots = \delta_{ij}$, where δ_{ij} as the Kronecker delta equals to 1 when *i=j*, otherwise 0. Thus, all state vectors are normalized, their inner product summing to 1 because their eigenvectors are equal (i.e., *cos* 0 deg = 1); it also means that the dot product of the two elements of a bistable vector is 0, and that the probabilities of measuring interdependent (or bistable) factors always sums to 1. This causes classical measurement uncertainty; i.e., when the probability of one bistable factor goes to zero, the other goes to 1.

If ψ was a simple column vector representing the state of its independent elements, putting aside manipulations to find the eigenvalues, there would be little ambiguity in constructing conceptual models or in understanding them based on what amounts to a convergent, rational process. Assuming that intuition is a stable interpretation of reality, conceptual difficulties arise and intuition fails when interdependence (groupiness) is introduced. Beginning with simple bistability, ψ becomes a superposition of two orthogonal but factorable states, such as an observation and an action; a republican and a democrat; or a single tribal ingroup and outgroup (e.g., Lawless et al., 2011). Putting time evolution aside, we gain insight into a static situation by letting $|0>$ be the name of a column vector that represents one of the orthogonal factors of a basis, and $|1>$ the other (e.g., we arbitrarily set observation to $|0> = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$, and action to $|1> = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$); similarly, we could let a single person oscillate between being a conservative, represented by $|0>$, and a liberal, represented by $|1>$ (and vice versa); or ingroup *A* versus outgroup *B* [39]. Two orthogonal vectors $|0>$ and $|1>$ form a basis in 2-D (i.e., *cos* 90 deg = 0).

Interdependence. To model a group in a state of interdependence, we introduce the tensor product of independent elements, for example, $|0> \otimes |0>$, represented as |00>; and $|1> \otimes |1>$, represented as |11>. The basis for a 2-agent system becomes $\{|00>, |01>, |10>, |11>\}$. Factorability means independent objects, that any separable vector space *V* as by tensor decomposition into basis elements is not interdependent. i.e., given state vector $|\psi>$ in a system, where $V = V_1 \otimes V_2 \otimes \ldots \otimes V_n$, the state $|\psi>$ is separable *iff* $|\psi> = V_1 \otimes V_2 \otimes \ldots \otimes V_n$. Otherwise, $|\psi>$ is in an interdependent state. An example of a non-factorable state is:

$$|\psi> = \frac{1}{\sqrt{2}}(|00> + |11>), \qquad (3)$$

To prove, let $(a_1|0>+b_1|1>)(a_2|0>+b_2|1>)=\frac{1}{\sqrt{2}}(|00>+|11>)$.

However, no combination of *a*'s and *b*'s exist such that a_1b_2 and a_2b_1 are both zero. Moreover, trying to break equation (3) into separable elements not only loses information, but also produces two incomplete states that cannot be recombined to reproduce the original state of interdependence.

Incompleteness and uncertainty. An individual's beliefs might be altered by new information but confirmation bias makes it unlikely that contradictory new information will be judged objectively by a committed believer (Darley & Gross, 2000), or even appreciated by a neutral believer. Avoidance of cognitive dissonance keeps most important attitudes and beliefs of humans stable indicating that conflict is necessary to change strongly held beliefs (Lawless et al., 2013). Together, these two biases make it unlikely that a leader of one political view (e.g., conservative or liberal) would entertain an opposing viewpoint, especially when entertaining such a view threatened power, status or access to resources under control.[10]

To simplify what constitutes a complexity of its own, assume there are teams of ideologues on either side of an issue, and that all others are swing voters ensconced in the neutral camp. For those in a political swing camp, we postulate that both views are held simultaneously in an indeterminate state of interdependence. For a single social agent in a superposition of orthogonal factors (opposed beliefs; or beliefs and actions), we propose:

$$|\psi>=a|0>+b|1>, \qquad (4)$$

with the basis for a single agent written as {|0>, |1>}, where $|a^*a'|=a^*a=a^2$ (here *a'* is the complex conjugate that we use to represent the oscillations caused by an illusion) gives the probability of a social object being found in state |0>, with b^2 giving the probability of being in state |1>. But, for an individual, this state vector is factorable, suggesting that the oscillating (conflicting) perspectives for independent neutral individuals may be simply aggregated to reconstruct the oscillation.

While equation (4) is easily factored; breaking apart a bistable state of superposition leads to a loss of information, producing incompleteness about the interdependent state. The effect of measuring *a* in equation 3 produces incomplete information about the measurement of *b*, the measurement problem.

[10] An example would be the US government shutdown that happened in October 2013.

Evidence of incompleteness for groups

The function of a group is to multitask. Multitasking with agent-1 and agent-2 forces them to focus on their individual tasks to manage the work-flows and communications between them to constitute the elements of a multitask, reducing the information available to them about their own performances.

The evidence from studies of organizations: First, Bloom and colleagues (2007) found that the estimation by managers of their firm's performance was unrelated to the firm's actual performance. Second, a significant association between training and performance was found by Lawless and colleagues (2010) and that no association existed between the book knowledge of air combat skills and combat outcomes. Third, uncertainty in the observations of better-run organizations was found to become noise (Lawless et al., 2013). Fourth, despite that most mergers fail (Andrade & Stafford, 1999), they are often pursued to offset a vulnerability, to gain a new technology, or to remove a competitor, but also to transform a business model for an organization that is failing

In sum, as Galton discovered when a crowd of independent individuals was able to accurately estimate the weight of an ox, groups that process all of the available information are more likely than any one individual to be correct. But when a group acts as one under maximum groupiness, it loses its ability to process all of the external information; the tradeoff is that the group becomes better at cooperating to multitask to derive the solution of a well-defined problem.

Modeling competing groups with limit cycles. We postulate that at the level of individuals and groups, there is a constant competition to focus on the orthogonal functions for observation and action, orthogonal views like conservatism and liberalism, or orthogonal membership in tribe *A* or tribe *B*. The competition between these orthogonal functions results in limit cycles (May, 2001).

Limit cycles depend on the free flow of neutrals to different (ideological, commercial, scientific, etc.) belief positions (a tenet of capitalism). Limit cycles can be suppressed under authoritarian rule. In a dictatorship, social stability is maintained by censoring information (May, 1973); i.e., by forcibly setting *a* or *b* to zero. But while social control is gained, in that incomplete information governs, the opportunity for mistakes increases dramatically (e.g., from Lawless et al., 2013: DOE's mismanagement of nuclear wastes prior to 1985; China's air and water contamination today; the USS Vincennes shoot-down of an Iranian airbus in 1988, killing all aboard; and the USS Greeneville's collision with a

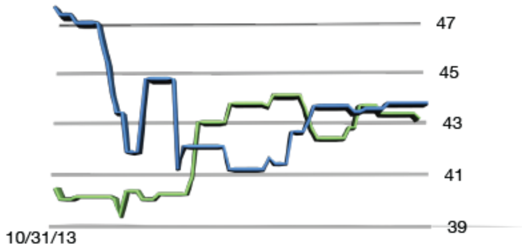

Figure 1. Instead of a limit cycle (i.e., portraying N_1 versus N_2; in May, 1973), we display the data with N over time, t. In the forthcoming campaign for Representatives and Senators for the Democratic (blue) and Republican (green) Party, the data represents the "Generic Congressional Vote" obtained by averaging poll numbers collected and published by Real Clear Politics (collected from October 31, 2013 to January 6, 2014; this, past and current data can be found at http://www.realclearpolitics.com/epolls/other/generic_congressional_vote-2170.html). Three limit cycles are shown of decreasing magnitude: From 11/25-12/17; from 12/17-12/25; and from 12/25-12/30.

Japanese fishing boat, killing nine of its tourists and crewmembers).

Compared to a collection of independent individuals, we had initially assumed that the entropy (*S*) is set to zero for a perfect team, the driving motivation to form a tribe. We now justify this assumption in the limit as follows (and contradict it later). Transaction costs are lower for individuals inside of a firm performing the same functions as for those same individuals multitasking in a firm (Bowles, 2012). This cost differential motivates the six-sigma processes designed to reduce waste in a firm, thereby impeding the tradeoffs a firm must make to find the new sources of free energy needed to adapt or to innovate (Conant, 1976), unexpectedly generating more entropy in a changing environment (May, 1973), possibly setting a firm up for failure later on.

Equation (2) does not allow us to capture tradeoffs. To do this for two operators, *A* and *B*, we write:

$$\left[A,B\right] = AB - BA. \tag{5}$$

When two operators representing two different tribes have the same eigenvalue, then the operators commute: $\left[A,B\right] = AB - BA = 0$. With agreement between two erstwhile competitors, the combined social system is stable, no oscillations occur, nor do limit cycles exist (the goal of an autocracy). But when disagreement arises between two competitors, their two operators do not commute, giving:

$$\left[A,B\right] = iC, \tag{6}$$

where *C* is a measure of the gap or distance in reality between *A* and *B*. However, as multitasking improves, the tradeoffs between each group's focus on their tasks interfere with their meta-perspectives on how best to change or optimize tasks to improve performance (Smith & Tushman, 2005), motivating tradeoffs that may or may not be efficacious:

$$\sigma_A \sigma_B \geq \frac{1}{2}. \tag{7}$$

where σ_A is the standard deviation of variable *A* over time, σ_B is the standard deviation of its Fourier transform, introducing frequency, and the two together forming a Fourier pair that reflects tradeoffs. Interdependent uncertainty generates tradeoffs. For example, as uncertainty in a team's or firm's skills decrease, uncertainty in its observations increase.

The number 1/2 is equation (7) we liken to a "gap" in reality. Equations (2) and (5) reflect the existence of this "gap" in social reality, *C*, that permits social dynamics to operate. Social dynamics derive from the challenges to claims, social illusions (Adelson, 2000) and irrationality (Kahneman, 2011), feeding limit cycles (May, 1973). The evidence indicates that the conscious awareness of signals takes about 500 msecs, but under decision-making, it can extend to several seconds (of at least 7 secs) before a human's consciousness becomes aware of its "desire" to switch to a new choice (Bode et al., 2011) that can then be articulated by the human brain's running narrator (Gazzaniga, 2011), the latter often construed as "free will".

Gaps

Gaps are needed to create a state of superposition over a claim, to process the challenges that establish the oscillations between claims, giving observers time and space to process sequentially the information derived from opposing perspectives. But the human motivation is to believe that knowledge processing is too cumbersome, leading to the various illusions such as that a merger reduces overcrowding in a collapsing market, that six-sigma processes safely improve profits, or that market returns improve by chasing market leaders. The motivation in these and other illusions is to ignore, reduce or replace the "gaps" in reality with a rational approach (one without gaps) instead of an emphasis (focus) on problem solutions.

Despite the accumulating evidence against the

traditional model, it remains rational (e.g., Bayesian). Silver (2012) concluded that the brain forms and continually updates a set of Bayesian "priors" learned over a lifetime used retrospectively to interpret new data that corresponds to its environment. But Silver's technique of aggregating polling data copies Galton's insight. The more important question is why Democrats and Republicans look at the same data but interpret it differently at the same time, thereby generating bistable illusions, conflict and oscillations. Numerous examples exist; e.g., R.A. Fisher, the esteemed statistician and evolutionary biologist, argued against the new evidence that smoking cigarettes would cause cancer; but Fisher was a smoker (Stolley, 1991), likely the cause of his not accepting the new evidence.

Conclusion

We have argued that interdependence combines with cognitive dissonance to make those of us who adopt strong beliefs act to suppress both our internal cognitive narrator, known as confirmation bias (Darley & Gross, 2000), but also the alternative views of our ingroup, forming the ingroup-outgroup bias (Tajfel, 1970). When these beliefs are unchallenged, they give the illusion of stable reality; but when challenged, they drive the oscillations of social behavior between competing teams, tribes, or firms across a system. Thus, the presence of alternative views in the decision process is not only the end of certainty that motivates tradeoffs (equations 4 and 7, respectively), but these Nash equilibria are also the source of information that competition generates for observers to process that preclude, reduce or mitigate tragedies (e.g., no modern democracy has ever suffered from famine; in Sen, 2000; and no modern democracy has ever started a war against another democracy; in Wendt, 1999). To defend an individual, Chagon (2012) concluded that people find safety in numbers of their own. However, although not very popular to any single tribe of Republicans or Democrats, competing religions or different races, nonetheless, it is the competition for the strongest idea that has become the modern foundation of free speech (Holmes, 1919).

Without competition, information incompleteness impedes social evolution. But with conflict and its management, indirect control of hybrid teams may be feasible. Social uncertainty spontaneously generates interdependence, just as interdependence generates social uncertainty. Both require a "gap" in reality that promotes competition as neutrals sort through the interpretations when they are free to make the best choice, switching back when a choice does not pan out, forming limit cycles that indirectly provide social control. Social information must remain incomplete, forcibly true under dictatorships to maintain direct control (May, 1973/2001), but inescapably true in democracies with working checks and balances. However, unlike dictatorships, the search for completeness in democracies leads to social evolution. Thus, all things considered, social (political) predictions made in democracies are more likely to occur than in dictatorships.

Finally, we began by setting the baseline entropy for well-functioning teams to zero. We need to revise it to underscore the cognitive difficulty implied by equation (3) for two or more agents multitasking together in a state of superposition. Equation (3) suggests on the one hand how a team or an organization can perform at a high level, but also why on the other hand they are incomplete witnesses of their performance. How can agents generate the data in Figure 1 for equation (3) or (5)? We suspect that a conflict center creates interference among superposed neutrals; that winning a debate or selling more computer products on one day somewhat suppresses a conflict center's complementary element, producing stable results; that a tie causes no movement in the results; and that a more competitive counterattack from a previously failing candidate or firm creates the return arm in the results that builds a limit cycle to exploit the gaps in reality.

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